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Use of radiometrics for bioregional conservation evaluation and wildlife habitat modelling in Central Australia

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ABSTRACT

Airborne geophysical methods have traditionally been used in geological mapping and the exploration for valuable minerals. Radiometric surveys measure the distribution of uranium, thorium and potassium in the Earth's crust, by recording the gamma-ray radiation emitted during the decay of these elements. Approximately 90% of measured gamma rays are received from the top 30 cm of the ground. These measurements enable the interpretation of rock and soil types. These data can be used to define soil types, and radiometrics may help differentiate key discharge and recharge zones at the catchment level. However, the application of airborne geophysical technologies to other areas of land and resource evaluation remains limited despite the rapid development of these technologies over the past decade. In this paper we introduce a study investigating the utility of radiometric data for predicting vegetation community patterns and wildlife habitat in the arid zone. We test for statistical relationships between the concentrations of the elements uranium, thorium and potassium and terrain characteristics such as slope and aspect. We then examine the relationship between these elements and mapped vegetation communities, and the use of radiometric data as a surrogate predictor of wildlife habitat. To the best of our knowledge, this is one of the first investigations of its type for the Australian arid zone.

KEYWORDS: radiometric data, bioregional surveys, biodiversity conservation, central Australia, geophysics technologies

Introduction

The arid zone represents around 70% of the Australian land mass and supports a significant component of the continent's biological diversity (Williams et al. 2001). Although the region has not been subject to the extensive clearance of native vegetation that has occurred in many other parts of Australia, European occupation has brought many changes to arid landscapes and its indigenous people. Pastoralism, introduced species such as the rabbit and fox, and altered patterns of fire have modified and degraded rangeland ecosystems and the biota. One of the most striking impacts has been the extinction and significant reduction in geographic range experienced by the mammalian fauna (Morton 1994). Of the 72 species of terrestrial mammals known originally from the arid zone, 11 have become extinct and five are now confined to small, fenced refugia (representing tiny parts of their former range) and off-shore islands (Williams et al. 2001). Another striking feature of the arid zone is the very low level of conservation protection afforded to most landscapes and ecosystems compared to southern Australia (Connors et al. 1996, Williams et al. 2001).

In recognition of the need to put land use on a sustainable basis in the rangelands and conserve the environment, governments have begun to implement field surveys to improve understanding of biodiversity and the potential threats posed to it by human land uses. The diverse ecosystems of the arid zone have been classified into over 30 bioregions based principally on similarities in climate, terrain and vegetation (Williams et al. 2001). The aim is to develop improved land management and biodiversity conservation strategies for each region based, in part, on new information gathered during the field surveys of each bioregion.

Since field surveys of bioregions are time consuming and expensive, various geospatial technologies and modelling techniques have been employed in an endeavour to make the surveys more cost-effective and information-rich. These techniques include the use of satellite imagery, derived spatial coverages such as terrain, and predictive models of biodiversity. These approaches are used to direct survey work and/or to analyse the data collected during the surveys to enhance understanding of the diversity of ecosystems and wildlife habitats. Spatial variability in geology, regolith, and surface and sub-surface hydrology can have a significant influence on vegetation and wildlife (e.g. Morton 1994, Dunkerley and Brown, 2002), but collectively fine-scale spatial information on geology, soils and hydrology is problematic and the present availability of these data is typically limited. Since 1981, the Northern Territory Geological Survey has been flying semi-regional airborne magnetic and multi-channel radiometric surveys on a prospectivity priority basis over mineral fields and basement terrains. In many of parts of the arid zone these airborne geophysical data sets are the most complete representation of the geology presently available, and various researchers have investigated landscape, geomorphic and hydrological processes and mineralogical patterns using these data (eg. Woodcock *et al*. 1997, Pickup and Marks 2000, 2001).

In this paper we introduce a study investigating the utility of radiometric data for predicting vegetation community patterns and wildlife habitat in the arid zone. We test for statistical relationships between the concentrations of the elements uranium, thorium and potassium and terrain characteristics such as position in landscape, slope and aspect. We then examine the relationship between these elements and mapped vegetation communities, and the use of radiometric data as predictors of wildlife habitat. He radiometric data relate directly to the mineralogy of the region, not the vegetation. However, this form of technology can be used to characterise soils and geology which can be used for studies of vegetation and associated fauna. To the best of our knowledge, this is one of the first investigations of its type for the Australian arid zone.

Study area, dominant vegetation and fauna

The Burt Plain bioregion represents one of several bioregions located in central Australia. It was chosen as a case study to test conservation evaluation techniques because it encompasses a variety of ecosystems, supports a range of land uses, and biological data are available for the area. The Burt Plain bioregion is located immediately to the north of Alice Springs in the Northern Territory. It is sparsely populated and covers a total area of 73 972 km^2 or 7 381 727 hectares (Figure 1). Most of the land in the bioregion is used for cattle grazing with lesser areas used for purposes including conservation, mining and tourism. Land tenure is mainly pastoral leases and freehold (83.6%), with 14.7% Aboriginal freehold and only 0.25% reserved area (Connors *et al.* 1996), which includes the Dulcie Ranges National Park. The Burt Plain bioregion is dominated by flat to undulating plains and low rocky ranges of Pre-Cambrian granites (Figure 2). The rivers of the arid zone are usually dry but rise rapidly to flood levels after substantial rain. The annual average recorded flow of the two major rivers which occur in the bioregion, the Todd and the Finke is 60 Mm^3 and 75 Mm^3 respectively (Hooper, *et al.* 1987). Surface water in the bioregion is drained by a number of southerly and easterly flowing river systems.

There are 25 vegetation communities in the Burt Plain bioregion (as delineated by the 1:1 000 000 Northern Territory Vegetation Types Map). Of those 25, four dominant vegetation communities occupy approximately 73.3% of the bioregion. The four communities comprise tall-open and low-open shrubland and woodland characterised by a few dominant species such as *Acacia aneura* and A, estrophiolata, and grassland characterised by spinifex. Throughout this paper ‘Mulga’ is used as a common name for *Acacia aneura* while ‘mulga’ is used to describe plant communities dominated by Mulga. *Acacia* woodlands and shrublands occupy large areas of Central Australia, with Mulga *(Acacia aneura)* having by far the largest representation. Mulga is a small tree growing to about 5 m in height and found across extensive areas of arid Australia (Figure 3). Williams (2002) reported that Mulga dominated communities, together with hummock grasslands wooded with Mulga, are estimated to occupy 1 500 000 km^2 or about 20% of the continent. At regional and local scales, mulga may occur as continuous stands or as patches interspersed with a variety of other plant species such as Spinifex (Williams 2002). In central Australia, mulga is found on a range of landforms including rocky hillslopes, at the base of hills and rock outcrops (where it receives additional water by run-off from adjacent hills and low ranges), and in swales. Mulga generally occupies soils of intermediate fertility and, though found on a variety of soils, large stands are most commonly found on red earths, which are light textured with hard coherent subsoil.

Dunkerley (2002) described the spatial patterns of soil moisture and infiltration rates in a groved mulga woodland in arid central Australia.

Detailed studies on the indigenous fauna of mulga have largely only been undertaken in the last 10 years or so (eg. Reid et *al.* 1993; Recher and Davis 1997; Landsberg et *al.* 1997). These studies demonstrate that mulga contains rich faunal assemblages, as might be expected for such a dominant element in the landscape. Williams (2002) noted that different animals have different degrees of reliance on mulga for food and shelter.

Methods

Data sources: Gamma ray, terrain elevation and magnetic data were acquired for the Alice Springs area of central Australia from the Northern Territory Department of Mines and Energy. Surveys were flown at 400 m line spacing with a mean terrain clearance of 60 m in a north-south flight-line direction. Radiometric and elevation data were sampled at 70 m intervals along each line. A total count measurement records overall radioactive levels and represents the combined measurements of potassium, thorium and uranium in counts per second. Spatial resolution is determined by the survey altitude of the aircraft, flight line spacing, the sampling intervals along that line and the sensitivity of the spectrometer onboard the aircraft.

Digital elevation model (DEM): The Australian Surveying and Land Information Group's (AUSLIG) standard product 'GEODATA 9 Second DEM Version 2' was used as a base Digital Elevation Model for this research. The DEM grid spacing is 9 seconds in longitude and latitude (approximately 250 m) and each grid cell has a value that represents the average elevation over the cell. The source data used to produced the DEM were:

- spot heights from GEODATA TOPO-250K relief the (25 000 points revised)
- linear watercourse features from the drainage layers of the GEODATA TOPO-250K Hydrography theme (9000 features revised)
- radar altimeter point elevation data for Lake Eyre
- trigonometric data points from the National Geodetic Data Base (19 000 points revised)
- spot heights (87 000), stream lines (11 000), sink point data (21 000), selected cliff lines and associated contour lines digitised from 1:100 000 scale mapping. The scale of the final product has a resolution between 1:250 000 and 1:500 000 (AUSLIG, 2001).

Two tiles of the Australian 9 Second DEM were required to cover the entire Burt Plain bioregion. Each tile nominally covers 6 degrees of longitude by 4 degrees of latitude. These were then converted to ArcInfo GRID format (using the ASCIIGRID command in the GRID module), mosaicked (using the mosaic command within GRID) and then clipped to the Burt Plain bioregion (using the GRIDCLIP command within GRID) to form one DEM for the entire case study region. The two tiles used were:

SF52 Lake Mackay	SF53 Alice Springs

DEM accuracy has root mean square elevation errors ranging between 7.5–20m across Australia. Unfortunately, it was not possible to create a higher resolution DEM using the flight line data for the entire target region due to the limited availability of the data and incomplete coverage across the entire region.

Information on vegetation types is based on (Wilson, 1990), who mapped NT vegetation types at 1:1 000 000 scale, defining 112 mapping units or vegetation communities. Mapping units were interpreted after recognition of vegetation patterns on Landsat (bands 4, 5 and 7), with reference to existing vegetation and land resource maps and some 1:500 000 Landsat imagery (Wilson, 1990). Modification of the mapping units were carried out after three years of field work, data analysis and re-interpretation, with further reference to geological, topographic and existing vegetation maps.

Over 12 185 vertebrate species occurrences have been recorded within the Burt Plain bioregion and recorded in the Northern Territory Parks and Wildlife Commission wildlife atlas. 168 bird species, 10 frog species, 53 mammal species and 106 reptile species have been recorded. Statistical modelling of species habitat was done using the Species Distribution Modelling Toolkit (SPMODEL) software (Bennett et al. 1997). Species with greater than 10 records were analysed with SPMODEL software. Relationships between the presence of a species and mapped environment variables were generated using GLM regression modelling techniques. These models could then be used to predict the probability of occurrence of a species at any given location, defined in terms of its environmental attributes. Interpolating model results using selected environmental variables produced bioregional maps of the predicted probability of occurrence of species.

The grid coverage distance to water (dist) was calculated using the ARC/INFO command EUCDISTANCE with the original cover containing drainage lines and waterbodies at 1:250 000 provided by the Northern Territory Parks and Wildlife Commission. The grid coverage proximity to roads (rddist) was calculated using the ARC/INFO command EUCDISTANCE with the original cover containing roads at 1:250 000 also provided by the Northern Territory Parks and Wildlife Commission.

Results

Radiometrics and terrain: Statistical relationships between concentrations of uranium, thorium, potassium and their total count are given in Table 1. The concentration of these elements in the study area was strongly auto-correlated. Concentrations of these elements were found together and the spatial distribution of these elements was positively correlated with aspect. No statistical correlation was found between the concentration of these elements and aspect or slope.

Radiometrics and vegetation: Relationships between uranium, thorium, potassium, the total count and the four mapped dominant vegetation communities in the Burt Plain bioregion were investigated. No apparent relationships were found between these radiometric coverages and the mapped vegetation at this scale of analysis. However, while detailed analyses are yet to be undertaken, we suspect there are likely to be correlations between some of the less dominant vegetation communities occurring at higher elevation and the coverages for thorium and the total count. An example of the spatial variation in the total count for the radiometrics coverage and the mapped vegetation is shown in Figure 4.

Radiometrics and fauna: A range of vertebrate fauna were examined to determine the potential of the radiometric coverage to act as a predictor of wildlife distribution. Radiometric data were found to be useful for developing statistical predictive models of three fauna species in the Burt Plain bioregion: Red Kangaroo, *Macropus rufus*; Desert Dunnart, *Sminthopsis youngsoni*; and rabbit, *Oryctolagus cuniculus* (Figures 5–7). The predicted probability of the occurrence of the Red Kangaroo was negatively correlated with the concentration of thorium, while the predicted occurrence of the Desert Dunnart was positively correlated with the concentration of potassium. Three independent variables (distance to nearest artificial watering point, total count, uranium) were identified as statistically significant in the probabalistic model for the rabbit. The predicted probability of occurrence of this introduced species was negatively correlated with the concentration of uranium and total count (Figure 7).

Table 1 Summary of statistical analyses of radiometric and DEM data: top – univariate statistics; middle – covariance matrix; bottom – correlation matrix

	Min	Max	Mean	Stdv
Uranium	–1.041	32.1668	2.75555	1.33047
Thorium	–3.711	93.4595	10.9352	6.5264
Total Count	–8.000	195.227	33.4035	18.0632
Potassium	0	8.04574	2.1191	0.882442
Aspect	–1	360	174.868	115.586
Slope	0	26.243	0.744667	1.36353

	Uranium	Thorium	Total Count	Potassium
Uranium	1.77016	7.00099	20.3466	0.878102
Thorium	7.00099	42.5939	110.532	4.41091
Total Count	20.3466	110.532	326.278	14.1641
Potassium	0.878102	4.41091	14.1641	0.778703
Aspect	117.819	691.24	1924.47	69.7694
Slope	0.798428	3.35896	10.0891	0.384196

	Uranium	Thorium	Total Count	Potassium
Uranium	1	0.806269	0.846625	0.747916
Thorium	0.806269	1	0.937603	0.765894
Total Count	0.846625	0.937603	1	0.888604
Potassium	0.747916	0.765894	0.888604	1
Aspect	0.766132	0.916323	0.921746	0.684026
Slope	0.440114	0.377456	0.409632	0.319302

Discussion

The aim of this contribution was to introduce a study investigating the utility of radiometric data for predicting vegetation community patterns and wildlife habitat in the arid zone based on the Burt Plain bioregion. The data presented form part of a doctoral study by the senior author in the region. Our preliminary analyses suggest that radiometric data sets involving the radioactive elements uranium, thorium and potassium and vegetation may have use as surrogates or predictors of biodiversity patterns at the landscape level. We tested for statistical relationships between the concentrations of the elements uranium, thorium and potassium and terrain characteristics such as position in landscape, slope and aspect, but only found a statistical correlation between these elements and aspect using a nine second DEM. The basis of this correlation needs further investigation and warrants analysis using a higher resolution DEM. Pickup and Marks (2001) used airborne gamma ray survey data to provide information on potassium, thorium and uranium concentrations in surface soil and rock in a similar area of central Australia. They reported that coverages of these radioelements, when combined with a 100 m grid cell DEM, allowed tracing of paths of sediments at the catchment scale. The tracing of these paths permitted an improved understanding of erosional and depositional events including episodic patterns of flooding in the area. The gamma ray data showed consistent variation with slope. Further work is required to clarify any potential quantitative relationships between the three radioelements and mapped vegetation communities, especially those rare and geographically restricted communities found at higher elevation in the ranges of the bioregion. Only three probabilistic models were developed for fauna occurring in the bioregion where one or more of the radioelements were statistically significant independent variables. At present, explanation of the biophysical functions that these variables play in influencing habitat is unclear, but is the subject of ongoing work. The utility of radiometrics data for wildlife habitat modelling will be explored further using alternative quantitative modelling techniques and presence/absence records for target faunal species.

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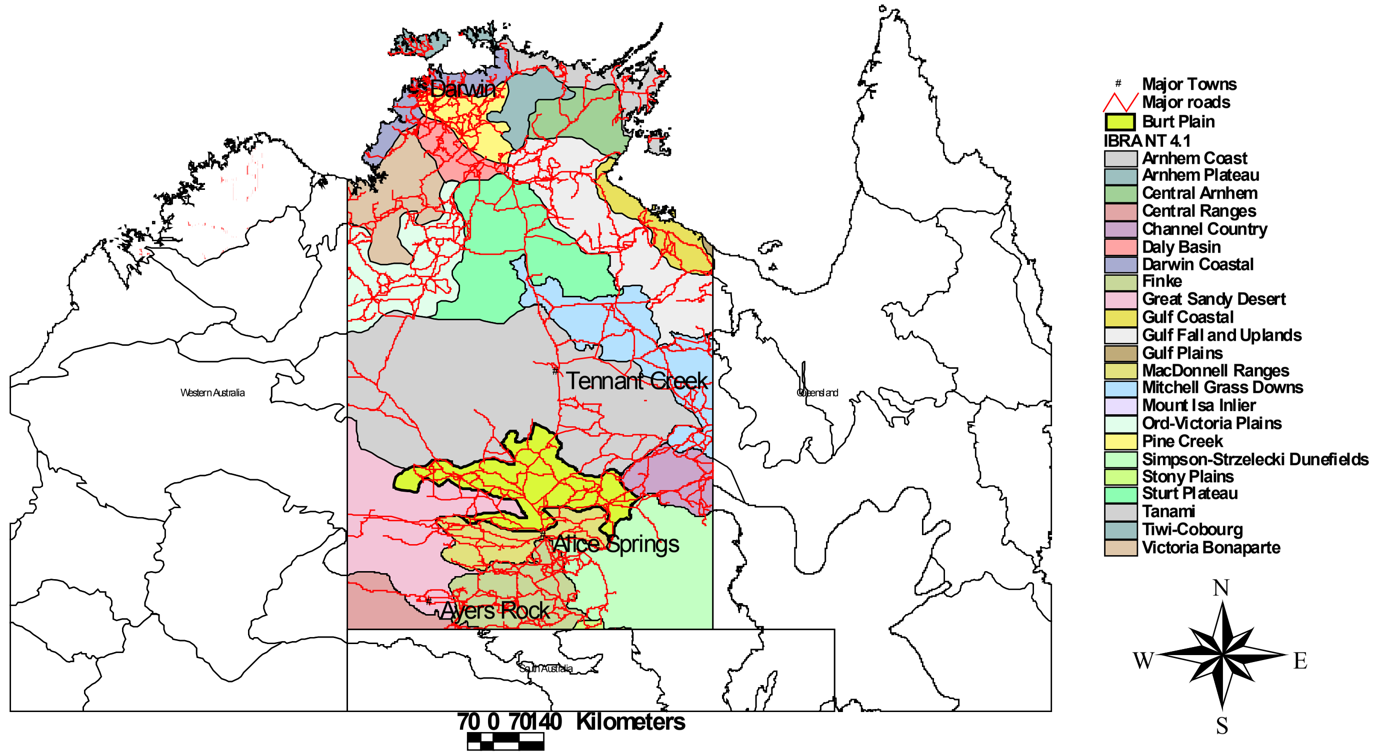


Figure 1 Location of Burt Plain bioregion, Central Australia, Northern Territory

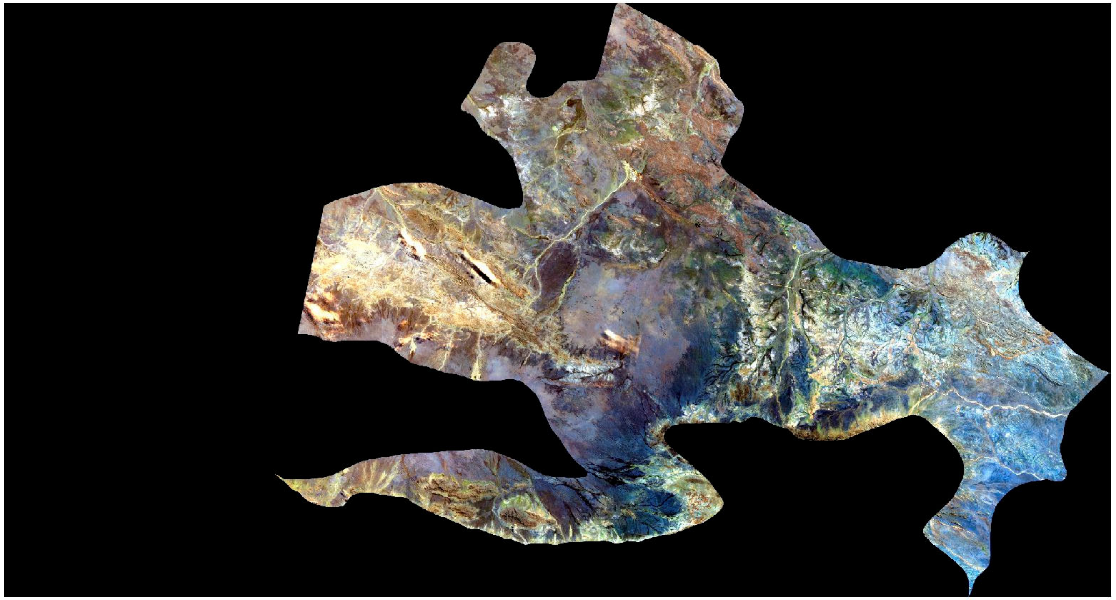


Figure 2 Landsat ETM7 mosaic of Burt Plain bioregion utilising Bands 1–5, 7—Central Australia, acquired March 2000, 30 m resolution, Datum AGD66

Figure 3 **Oblique aerial photo of mulga, Central Australia; source: Ludwig et al. 1997**

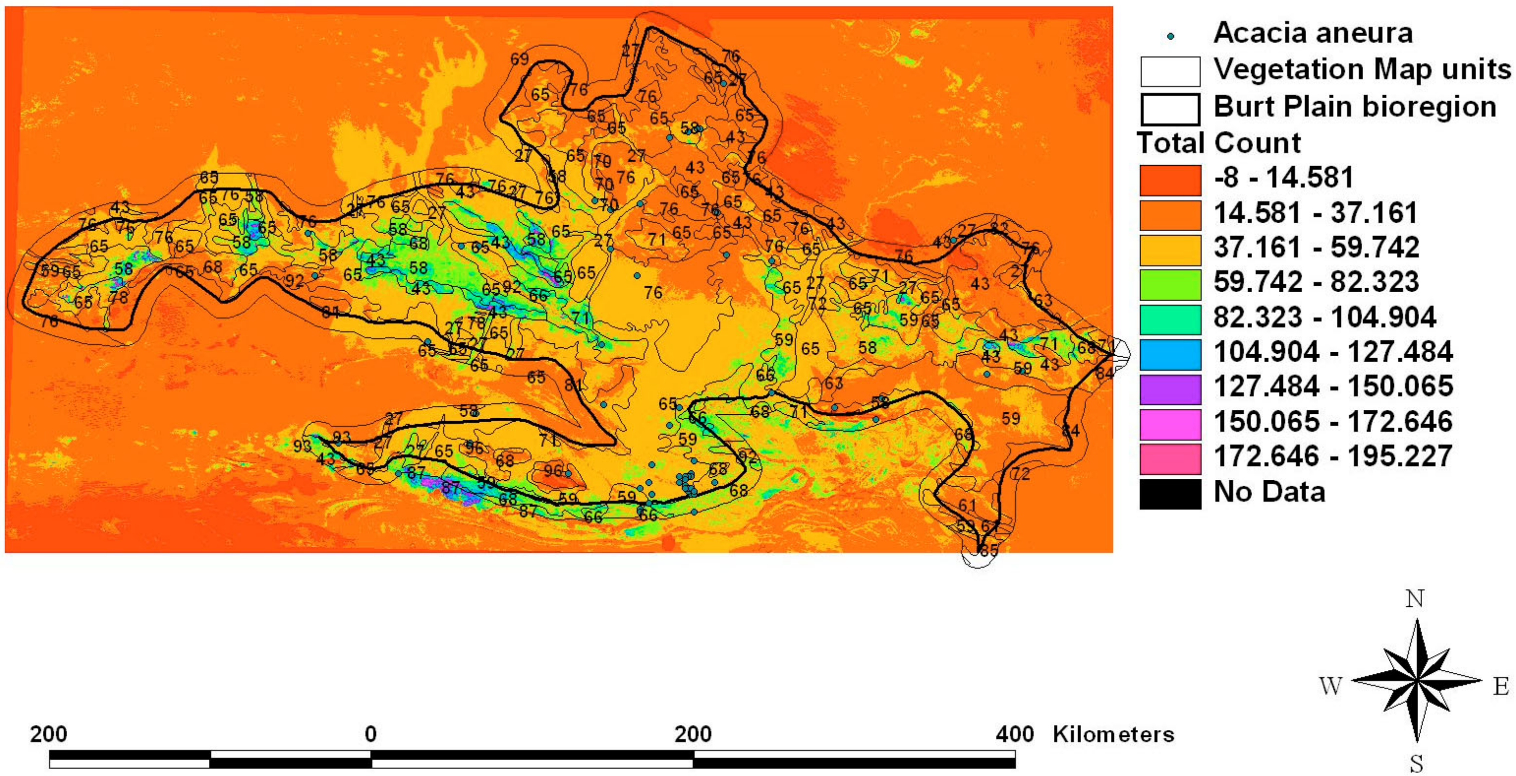
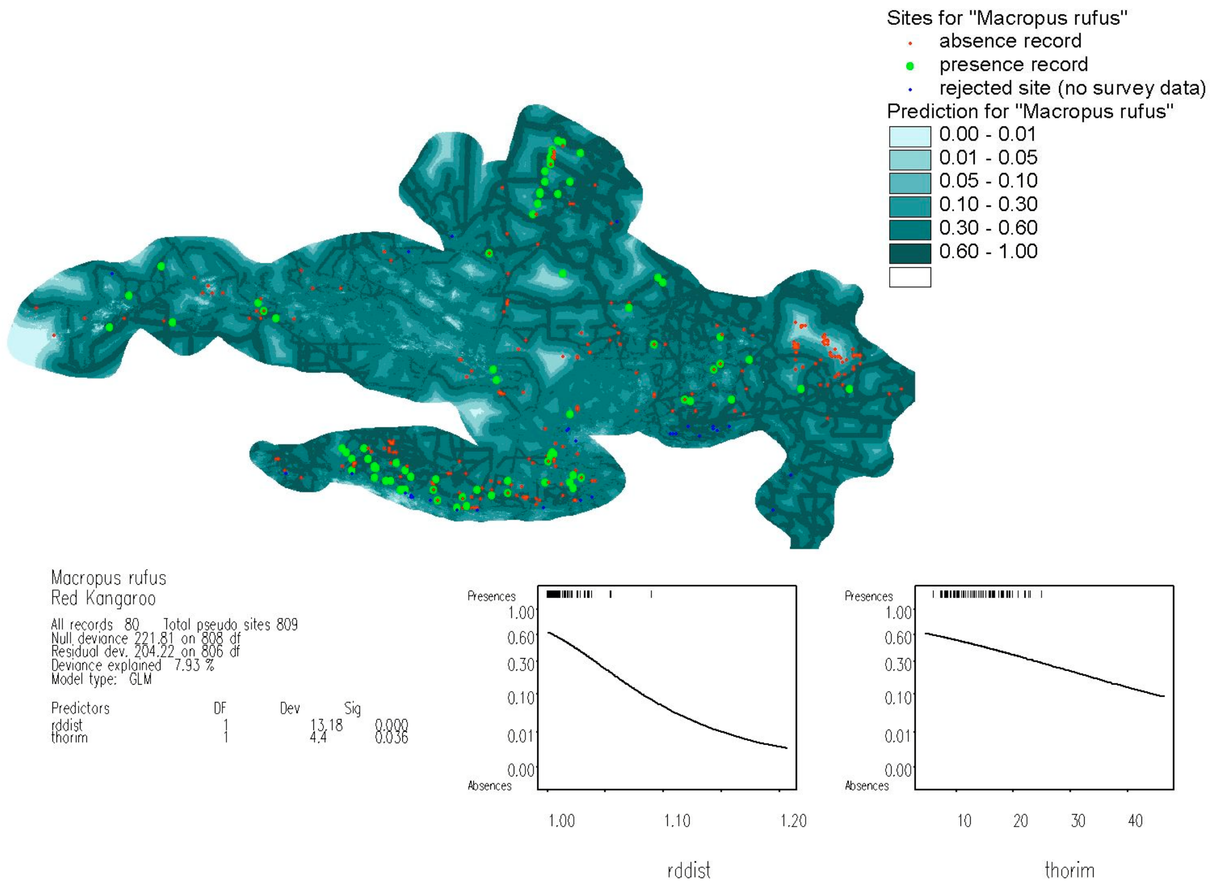


Figure 4 Total count vs vegetation



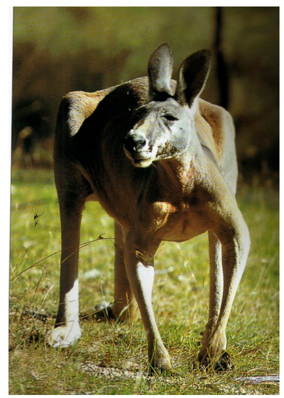
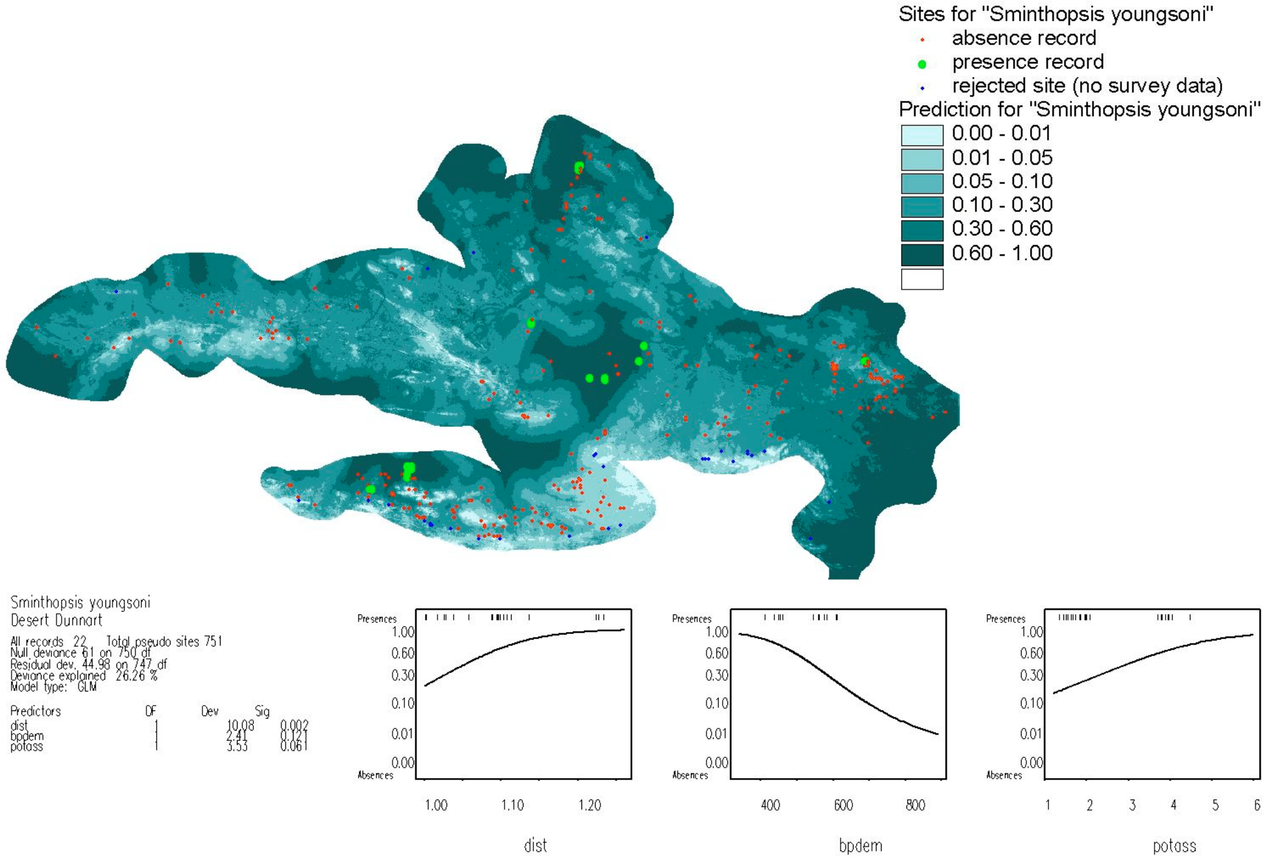


Figure 5 Predicted distribution of ***Macropus rufus*** (Red Kangaroo) and results of relationship with distance to road and thorium (see text for explanation)



Dunnart
(Sminthopsis youngsoni).

Figure 6 **Predicted distribution of *Sminthopsis younsoni* (Desert Dunnart) and relationship with distance to water, elevation and potassium (see text for explanation)**

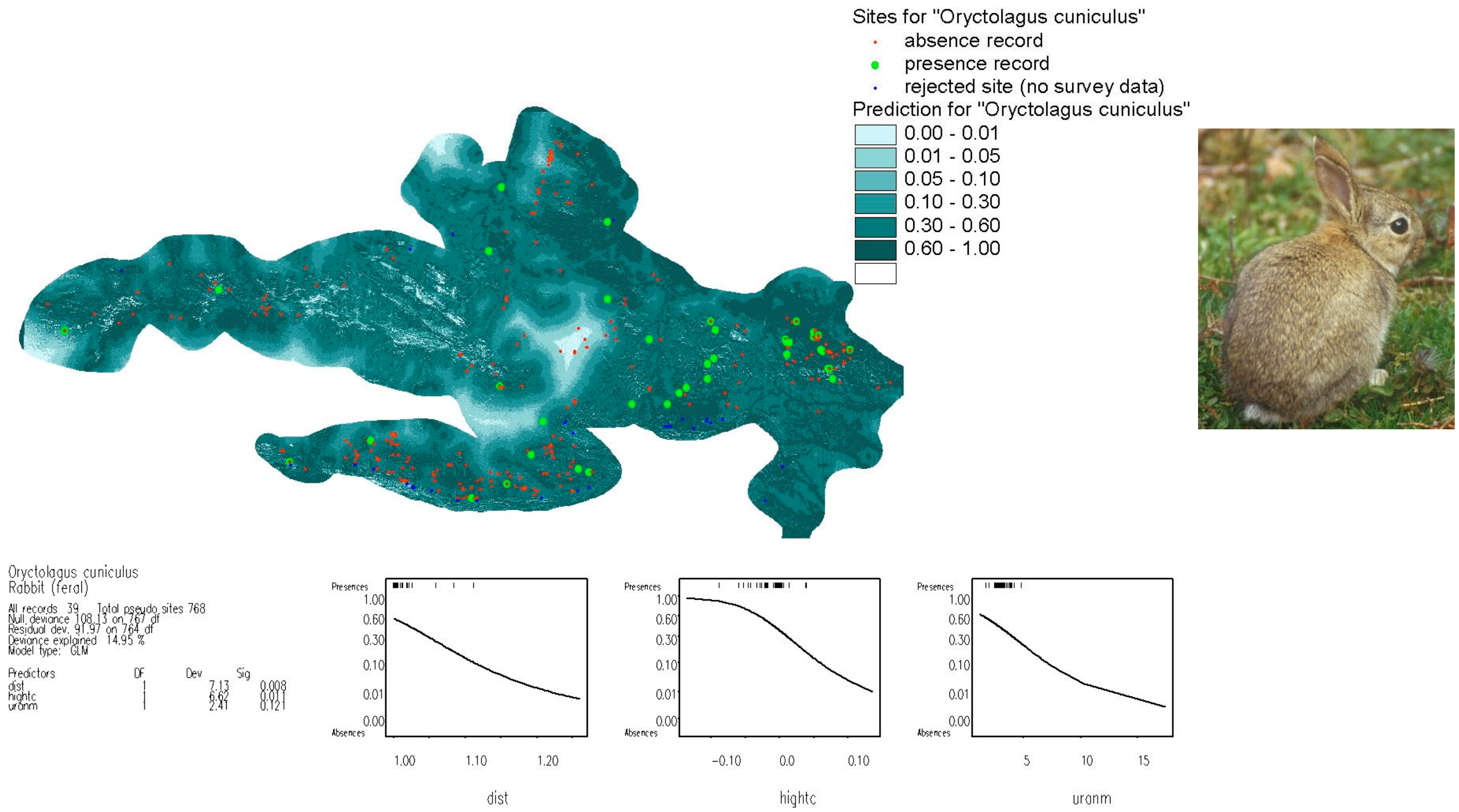


Figure 7 **Predicted distribution of *Oryctolagus cuniculus* (Rabbit) and relationship with distance to water, high pass total count and uranium (see text for explanation)**